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Organic Phosphorus Content of Some West Virginia Soils

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The information in this bulletin is based on portions of theses submitted by Raese and Reese in partial fulfillment of the requirements for Master of Science degrees.

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Organic Phosphorus Content Of Some West Virginia Soils

Everett M. Jencks, John T. Raese and Charles D. Reese

THE phosphorus content of soils has been found to range from 100 to 4,000 pounds per acre and to average about 1,000 pounds per acre (10). Most of this phosphorus exists in a diversity of relatively inert organic and inorganic compounds, and, consequently, only a small portion of the total, amounting to 1 per cent or less (5), becomes available to plants during the growing season.

The source of most soil phosphorus is the apatite group of minerals, primarily fluorapatite and hydroxyapatite. As the soil weathers, these minerals release phosphorus to the soil solution. Most of the phosphorus released becomes incorporated into a variety of organic and inorganic compounds of limited solubility. In acid soils, inorganic phosphates react with iron and aluminum salts or colloids and clay minerals to form complexes that render much of the phosphorus unavailable. In alkaline soils, the phosphates react with calcium to form insoluble calcium phosphates which are primarily responsible for causing low levels of available phosphorus (5, 8, 12, 22).

It has been reported that up to 40 per cent of the total phosphorus in mineral soils may be in organic form; in organic soils, it may be as high as 80 per cent (2). Soil organic phosphorus compounds are derived from plant residues and from synthesis by soil microorganisms. Organic phosphorus has been found to correlate positively with organic matter, although the ratio between organic phosphorus and organic matter is higher in acid soils than in alkaline soils. This indicates that organic phosphorus is more resistant to decomposition in acid soils (15, 18). Reports also indicate that the ratio of organic phosphorus to organic matter is lower in organic soils than in mineral soils. Although organic phosphorus normally decreases with the depth of the soil, subsoil organic matter generally contains a higher percentage of organic phosphorus than surface soil (7, 15).

Soil organic phosphorus is composed primarily of phospholipids, nucleic acids, and phytin (6). Phytin, which includes phytic acid (inositol hexaphosphate) and its salts, has been shown to be the major component. Bower (2) and Caldwell and Black (4) have reported that phytin may constitute up to 50 per cent of the organic phosphorus in soils. Phytic acid itself is not resistant to hydrolysis in soils, but the iron and aluminum salts that form in acid soils and the calcium and magnesium salts that persist in alkaline soils are resistant to hydrolysis and therefore accumulate (3, 9, 10).

Several experiments have been conducted to determine the value of organic phosphorus *per se* in plant nutrition but little has been accomplished (1). Most workers recognize that organic phosphorus must undergo mineralization in order to benefit plants. Unfortunately, the knowledge available at present is inadequate to evaluate the rate of mineralization of organic phosphorus in soils, especially under field conditions. Nevertheless, organic phosphorus, because of the high levels often found in soils, plays an important role in the phosphorus cycle and serves as a phosphorus reserve for plant utilization.

The study reported here was conducted to determine the total organic phosphorus and phytin phosphorus contents of some West Virginia soils and to relate these results to organic matter, total and available phosphorus, and pH.

Procedure

Soil samples for this study were collected by staff members of the Department of Agronomy and Genetics, West Virginia University, and by soil scientists of the Soil Conservation Service. Samples were selected from areas that had not been fertilized or limed. Those collected for analysis were air-dried, ground, and passed through a 60-mesh sieve. The A and B horizon of 34 West Virginia soils representing 17 soil series were analyzed for total organic and phytin phosphorus content. Determinations of total and available phosphorus, organic matter, and pH were included for comparison.

Total phosphorus was determined by the method outlined by Prince (16). The Truog (19) method was used to determine available phosphorus.

Organic phosphorus was determined by the method of Saunders and Williams (17), and it represents the difference between phosphorus extracted before and after destruction of organic matter by ignition. This method was compared with the method of Legg and Black (11) and was found to give more complete ignition because of the higher temperature used (550° C vs 240° C) and less hydrolysis of organic phosphorus with the more dilute acid extractant (0.2N sulfuric acid vs. conc. hydrocloric acid).

Anhydrous formic acid was used to extract phytin. This reagent has been found to extract organic matter from soil with little alteration of the chemical structure (14). Preliminary studies in this laboratory showed it is also a good extractant for phytin. Single dimension, ascending paper chromatography was used to determine phytin phosphorus. This method was successfully used (3, 20, 21, 22), and found to be rapid and accurate. Two per cent sodium hydroxide was used as the separatory solvent.

A 0.2 cc aliquot of the filtered formic acid extractant was spotted on Whatman #2 chromatography paper and dried in a stream of warm air. The paper then was placed in contact with the separatory solvent (2 per cent sodium hydroxide) in a covered glass cylinder and the solute allowed to ascend for 30 minutes. This paper was dried, sprayed with alcoholic ferric chloride, then with salicysulfonic acid, and again dried. This treatment caused organic phosphorus compounds to appear as white spots on a mauve background. Phytin was identified on the chromatogram by use of an Rf value of 0.6 previously determined by developing a chromatogram from pure phytic acid by the procedure outlined above. Once the phytin spots had been identified, they were cut from the paper, digested with 30 per cent hydrogen peroxide and the resulting inorganic phosphorus determined by a conventional method. The phosphorus so determined was considered to be phytin phosphorus. Approximately 97 per cent of the phytic acid phosphorus in the formic acid solution was recovered by the procedure outlined.

Organic matter content was determined by the chromic acid method outlined by Prince (16). Values for pH were obtained using a Beckman "Zeromatic" pH meter.

Results And Discussion

The results of chemical analyses for this study are presented in Tables 1 and 2 (Appendix). Statistical correlations were calculated between total organic phosphorus and phytin phosphorus and between each of these fractions and other soil characteristics. The data are given in Table 3 (Appendix).

The results show that organic phosphorus constitutes an appreciable portion of the total phosphorus in the soils studied. On the average, 42.3 per cent of the phosphorus in surface samples was organically combined. The average in subsoil samples was 27.7 per cent. The extremes for surface samples were 7.0 per cent and 65.8 per cent and for subsoil samples 13.4 per cent and 54.9 per cent.

In actual quantities, organic phosphorus in surface samples varied from 70 ppm to 827 ppm and averaged 265 ppm. The range in subsoil samples was 28 ppm to 589 ppm and the average was 136 ppm. All subsoil samples except a Huntington silt loam (#123) contained less organic phosphorus than their respective surface samples.

Statistical correlations of organic phosphorus with total phosphorus and with organic matter (Table 3) were highly significant as would be expected. Correlations of organic phosphorus with available phosphorus and with pH were not significant at the 5 per cent level, although the correlation with pH was just short of significance. Usually there is little relationship between organic phosphorus and available phosphorus, according to the literature (1). The failure of organic phosphorus to correlate significantly with pH in this study occurred, no doubt, because most of the soils investigated were strongly acid in reaction. In fact, 22 surface and 26 subsoil samples were below pH 5.0 and only 3 samples including both surface and subsoil samples were above pH 7.0 in reaction.

The ratio of phosphorus in organic form to organic matter was apparently higher in subsoil samples than in surface samples. On the basis of the average content of organic phosphorus and the average percentage of organic matter, this ratio was 1:155 in surface samples and 1:103 in subsoil samples.

Although organic phosphorus increased with increased organic matter, the relationship was not proportional. Soils higher in organic matter showed a lower percentage of organic phosphorus than soils lower in organic matter. This same trend has been found by others (15, 18).

There appeared to be little tendency for the percentage of total phosphorus in organic form to vary among regions. Poorly drained and very poorly drained soils contained larger amounts of organic phosphorus than well-drained and excessively drained soils, regardless of location. Under conditions of poor drainage, mineralization of organic phosphorus is retarded by lack of oxygen.

Regarding the effect of texture on organic phosphorus levels, no concrete conclusions can be drawn because most of the soils investigated were of medium texture, with only three fine-textured and two coarse-textured soils being included.

The results show that phytin phosphorus is an important component of the phosphorus fraction in the soils investigated. Surface samples ranged in content from 75 ppm to 750 ppm and averaged 245 ppm. Subsoil samples were generally lower than surface samples in phytin phosphorus, varying from 25 ppm to 500 ppm. The average for subsoil samples was 136 ppm. As the percentage of total phosphorus phytin, phosphorus ranged for 13.3 per cent to 63.1 per cent in surface samples and averaged 28.9 per cent. Subsoil samples varied from 10.1 per cent to 47.9 per cent and averaged 28.9 per cent.

Statistical correlations of phytin phosphorus with organic phosphorus, total phosphorus, and organic matter were highly significant. When compared with either pH or available phosphorus, no statistical significance was found.

The high correlation between phytin phosphorus and organic phosphorus, plus the fact that the organic phosphorus fraction was largely phytin, suggests that organic phosphorus levels in the soil studied may be influenced to a large extent by those factors that influence phytin levels. In some of the samples, both surface and subsoil, values for phytin phosphorus are very close to organic phosphorus values. The possible reason for this is the low pH values recorded for most of the soils sampled. According to some investigators (2, 10), phytin levels vary inversely with pH, presumably because of the formation of inert iron and aluminum phytates. No reports were found in the literature showing correlations between these two characteristics. Although the correlation between phytin phosphorus and pH was not significant in this study, little can be concluded because too few soils in the slightly acid to alkaline range were included relative to the number of strongly acid soils. Further study in this specific area is required.

Since organic phosphorus was so closely related to total phosphorus and since phytin phosphorus was closely correlated to total organic phosphorus, the high correlation between phytin phosphorus and total phosphorus is expected. Again, because total organic phosphorus was closely related statistically to organic matter, it would be expected that phytin, because of its high correlation with organic phosphorus, would correlate closely with organic matter. Moreover, it is reasonable to assume that those factors influencing the levels of organic matter also would affect phytin levels.

The fact that phytin phosphorus did not correlate with available phosphorus is reasonable for two reasons. First of all, phytin phosphorus was closely related to both total phosphorus and organic phosphorus. Total and organic phosphorus do not correlate significantly with available phosphorus in most soils (1). Secondly, since phytin is quite stable, it probably does not contribute materially to the soluble phosphorus in soils.

The tables show that values for phytin phosphorus sometimes exceed those for total organic phosphorus. This is a result of analytical error. Results from the ignition method may be low because of incomplete recovery of inorganic phosphorus and because of volatilization of this element during ignition. It also is possible that certain errors arise in the chromatographic technique used for phytin phosphorus when applied to certain soils.

The large amounts of organic phosphorus found in the soils investigated suggest that this form may be important from the standpoint of phosphorus-supplying power of West Virginia soils. Further studies including rates of synthesis and mineralization of organic phosphorus under various conditions in West Virginia soils are needed.

Summary

Organic phosphorus, phytin phosphorus, total and available phosphorus, and pH were determined in samples from the A and B horizons of 34 widely distributed West Virginia soils.

Organic phosphorus varied in surface samples from 70 ppm to 827 ppm and averaged 256 ppm. Subsoil samples were generally lower, ranging from 28 ppm to 589 ppm and averaging 136 ppm. As a percentage of total phosphorus, organic phosphorus ranged from 7.0 per cent to 65.8 per cent in surface samples and averaged 42.3 per cent. The range in subsoil samples was 13.4 per cent to 54.9 per cent with an average of 27.7 per cent.

Statistical correlations of organic phosphorus with total phosphorus and organic matter were highly significant. Correlations with available phosphorus and pH were not significant; although, with pH, it was just short of significance at the 5 per cent level.

The ratio of organic phosphorus to organic matter was less, on the average, in surface samples than in subsoil samples, being 1:155 and 1:103, respectively.

There was little difference among regions with respect to organic phosphorus content. Soils higher in organic matter and total phosphorus tended to be higher in organic phosphorus regardless of region. Poorly-drained soils as a group, because of their higher contents of total phosphorus and organic matter, were higher in organic phosphorus than well-drained soils.

Phytin phosphorus constituted an appreciable portion of the total phosphorus in the soils investigated. Surface samples ranged from 75 ppm to 750 ppm and averaged 245 ppm. Subsoil samples were generally lower in phytin, varying from 25 ppm to 50 ppm and averaging 136 ppm. On the basis of percentage of the total phosphorus, the variation in surface samples was from 13.3 per cent to 63.1 per cent and the average was 39.1 per cent. Subsoil samples were usually lower than surface samples, varying from 10.1 per cent to 47.9 per cent and averaging 28.9 per cent.

Statistical correlations of phytin phosphorus with organic phosphorus, total phosphorus, and organic matter were highly significant. As with organic phosphorus, phytin phosphorus did not correlate significantly with available phosphorus or pH.

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APPENDIX

TABLE 1. Organic Phosphorus Content and Related Data of Some West Virginia Surface Soils.

Soil Description and Laboratory Number	Organic Matter Per Cent	pH	Truog P ppm	Total P ppm	Organic P		Phytin P	
					ppm	Per Cent Total P	ppm	Per Cent Total P
I. Upland Soils of the Allegheny Plateau								
A. From Limestone and Shale								
1. Well Drained								
235 Westmoreland silt loam	1.45	4.3	19.2	917	264	28.8	180	19.6
237 Westmoreland silt loam	2.23	4.4	9.6	835	311	37.2	275	32.9
Average	1.84	----	14.4	926	288	33.0	228	26.3
B. From Sandstone and Shale								
1. Excessively Drained								
69 Dekalb loam	3.16	6.9	5.6	183	80	43.7	75	40.9
70 Dekalb stony loam	5.73	4.1	10.4	339	208	61.4	200	58.9
71 Dekalb channery silt loam	11.17	3.8	11.2	583	289	49.6	200	34.3
103 Gilpin silt loam	8.39	4.7	0.0	557	240	43.1	125	22.4
104 Gilpin silt loam	2.35	4.0	10.0	222	96	43.2	125	56.3
106A Gilpin silt loam	1.78	4.2	15.2	1030	455	44.2	475	46.1
174 Muskingum silt loam	2.37	4.4	5.6	200	87	44.0	180	37.5
Average	4.99	----	8.3	445	208	47.0	197	42.3
2. Well Drained								
56 Clymer fine sandy loam	2.74	4.4	8.8	174	72	41.4	75	45.9
57 Clymer silt loam	5.40	4.5	11.2	391	180	46.0	180	46.0
58 Clymer loam	7.02	4.8	11.2	804	411	51.1	180	49.8
Average	5.05	----	10.4	456	221	46.2	145	47.2
3. Imperfectly Drained								
63 Cookport silt loam	1.81	5.1	12.4	217	102	47.0	113	52.1
4. Poorly Drained								
144 Lickdale silty clay loam	5.08	4.5	9.6	652	328	50.3	274	42.2

TABLE 1—(Continued)

Soil Description and Laboratory Number	Organic Matter Per Cent	pH	Truog P ppm	Total P ppm	Organic P		Phytin P	
					ppm	Per Cent Total P	ppm	Per Cent Total P
II. Upland Soils Developed on Residual Limestone								
1. Well Drained								
98 Frederick silt loam	2.15	5.8	11.2	317	162	51.1	180	56.8
100 Frederick silt loam	9.56	6.2	15.2	752	325	43.2	100	13.3
116 Hagerstown silt loam	2.27	5.7	4.6	743	308	41.5	275	37.0
117 Hagerstown silt loam	2.17	7.1	29.6	835	296	34.4	275	32.9
Average	4.04	----	15.2	662	273	42.8	208	35.0
2. Poorly Drained								
11B Atkins silty clay loam	8.39	4.0	18.0	900	592	65.8	450	50.0
3. Very Poorly Drained								
83 Elkins silty clay loam	6.59	4.1	9.2	1365	827	60.6	750	54.9
85 Elkins silt loam	15.12	4.2	2.4	1287	691	53.7	513	39.9
Average	10.85	----	5.8	1326	759	57.2	632	47.4
B. From Limestone or Calcareous Shales								
1. Well Drained								
123 Huntington silt loam	1.69	6.8	177.6	1004	251	25.0	125	12.5
125 Huntington silt loam	3.65	5.5	20.8	1017	466	45.8	400	39.3
607 Huntington silt loam	4.27	6.5	22.0	887	421	47.5	400	45.1
801 Huntington silt loam	2.93	7.5	4.0	617	202	32.7	100	16.2
Average	3.14	----	56.1	881	335	37.8	256	28.3

TABLE 1—(Continued)

Soil Description and Laboratory Number	Organic Matter Per Cent	pH	Truog P ppm	Total P ppm	Organic P		Phytin P	
					ppm	Per Cent Total P	ppm	Per Cent Total P
III. Soils of the Ridge and Valley Region								
A. From Sandstone and Shale								
1. Excessively Drained								
5 Ashby loam	2.07	5.2	10.0	296	91	30.7	125	42.2
6 Ashby silt loam	3.45	4.3	8.4	809	251	31.0	250	30.9
42 Calvin silt loam	4.78	3.8	11.6	357	161	45.1	180	50.4
Average	3.43	----	10.0	487	168	35.6	185	41.2
IV. Soils of the Terraces								
A. From Limestone and Shale								
1. Well Drained								
230 Waynesboro loam	1.43	4.6	4.4	230	104	45.2	100	43.5
2. Imperfectly Drained								
166 Monongahela silt loam	3.37	4.8	4.0	661	285	43.1	250	37.8
168 Monongahela silt loam	3.07	4.6	6.0	422	143	33.9	100	23.7
382 Monongahela silt loam	0.66	4.5	2.4	243	83	34.2	150	61.7
Average	2.37	----	4.2	389	154	39.1	167	41.2
V. Soils of the Bottomlands								
A. From Sandstone and Shale								
1. Well Drained								
187 Pope sandy loam	0.88	5.2	3.6	1004	70	7.0	200	19.9
188 Pope	2.28	4.3	9.6	488	162	36.2	175	35.9
Average	1.58	----	6.6	546	116	21.6	188	27.9

TABLE 2. Organic Phosphorus Content and Related Data of Some West Virginia Subsoils.

Soil Description and Laboratory Number	Organic Matter Per Cent	pH	Truog P ppm	Total P ppm	Organic P		Phytin P	
					ppm	Per Cent Total P	ppm	Per Cent Total P
I. Upland Soils of the Allegheny Plateau								
A. From Limestone and Shale								
1. Well Drained								
235 Westmoreland silt loam	0.41	4.2	72.0	1491	217	14.6	150	10.1
237 Westmoreland silt loam	0.49	4.6	4.4	543	138	25.4	180	33.2
Average	0.44	----	38.2	1017	178	20.0	165	21.7
B. From Sandstone and Shale								
1. Excessively Drained								
69 Dekalb loam	0.24	4.7	6.0	117	28	23.9	50	42.7
70 Dekalb stony loam	1.12	4.6	6.0	274	110	40.1	80	29.2
71 Dekalb channery silt loam	1.21	4.3	6.0	291	75	25.8	100	34.4
103 Gilpin silt loam	0.97	4.3	3.4	378	68	18.0	25	6.6
104 Gilpin silt loam	0.68	3.9	10.0	230	48	20.9	100	43.5
106A Gilpin silt loam	0.56	4.1	18.0	865	264	30.5	180	20.8
174 Muskingum silt loam	0.29	4.4	8.8	235	78	33.2	50	21.3
Average	0.72	----	8.3	341	96	27.5	84	28.4
2. Well Drained								
56 Clymer fine sandy loam	0.57	4.5	7.2	165	44	26.7	50	34.2
57 Clymer silt loam	0.84	4.4	6.0	213	53	24.9	50	23.5
58 Clymer loam	0.81	4.4	6.0	357	100	28.0	100	28.0
Average	74	----	6.4	245	66	26.5	67	28.6
3. Imperfectly Drained								
63 Cookport silt loam	0.12	4.6	8.8	143	31	21.7	38	26.6

TABLE 2—(Continued)

Soil Description and Laboratory Number	Organic Matter Per Cent	pH	Truog P ppm	Total P ppm	Organic P		Phytin P	
					ppm	Per Cent Total P	ppm	Per Cent Total P
4. Poorly Drained								
144 Lickdale silty clay loam	2.01	4.7	10.0	443	127	28.7	75	16.9
II. Upland Soils Developed on Residual Limestone								
1. Well Drained								
98 Frederick silt loam	0.26	4.5	10.0	152	28	18.4	50	32.9
100 Frederick silt loam	0.47	4.3	8.4	248	61	24.6	100	40.3
116 Hagerstown silt loam	0.47	5.2	2.4	404	69	17.1	100	24.8
117 Hagerstown silt loam	0.33	6.7	16.4	565	123	21.8	125	22.1
Average	0.38	----	9.3	342	70	20.5	94	30.0
III. Soils of the Ridge and Valley Section								
A. From Sandstones								
1. Excessively Drained								
5 Ashby loam	0.43	6.7	12.4	370	78	21.1	50	13.5
6 Ashby loam	3.79	4.3	12.0	843	228	27.0	250	29.7
42 Calvin silt loam	0.67	4.3	12.4	343	95	27.7	100	29.2
Average	1.63	----	12.3	519	134	25.3	133	24.1
IV. Soils of the Terraces								
A. From Sandstone and Shale								
1. Well Drained								
230 Waynesboro loam	0.41	4.6	3.2	230	46	20.0	75	32.6
2. Imperfectly Drained								
166 Monongahela silt loam	0.50	4.6	4.0	365	69	18.9	75	20.5
168 Monongahela silt loam	0.36	4.3	4.0	261	35	13.4	75	28.7
382 Monongahela silt loam	0.14	4.8	1.6	217	35	16.1	80	36.9
Average	0.33	----	3.2	281	46	16.1	77	23.7

TABLE 2—(Continued)

Soil Description and Laboratory Number	Organic Matter Per Cent	pH	Truog P ppm	Total P ppm	Organic P		Phytin P	
					ppm	Per Cent Total P	ppm	Per Cent Total P
V. Soils of the Bottomlands								
A. From Sandstone and Shale								
1. Well Drained								
187 Pope sandy loam	1.18	5.0	2.8	213	30	14.1	80	37.9
188 Pope silt loam	2.08	4.6	10.8	417	141	33.8	175	41.9
Average	1.63	----	6.8	315	86	24.0	128	39.9
2. Poorly Drained								
11B Atkins silty clay loam	4.51	4.2	7.2	639	351	54.9	275	43.0
3. Very Poorly Drained								
83 Elkins silty clay loam	2.50	4.2	2.0	465	204	43.9	180	38.7
85 Elkins silt loam	16.15	4.3	0.0	1078	589	54.6	500	46.4
Average	9.33	----	1.0	776	397	49.3	340	42.6
B. From Limestone or Calcareous Shales								
1. Well Drained								
123 Huntington silt loam	1.16	6.0	20.0	687	267	38.9	80	11.6
125 Huntington silt loam	1.78	5.3	12.0	822	274	33.3	275	33.5
607 Huntington silt loam	2.00	6.0	4.8	787	350	44.5	250	31.8
801 Huntington silt loam	1.82	7.7	0.4	509	174	34.2	80	15.7
Average	1.69	----	9.3	702	266	37.7	171	23.2

TABLE 3. Correlation Coefficients of Organic Phosphorus Relationships.

Treatment	All Samples d.f. = 66	Surface Samples d.f. = 32	Subsoil Samples d.f. = 32
	r	r	r
Total Organic P vs Total P	0.920*	0.831*	0.791*
Total Organic P vs Organic Matter	0.708*	0.590*	0.793*
Total Organic P. vs pH	NS	NS	NS
Total Organic P vs Truog P	NS	NS	NS
Phytin P vs Total Organic P	0.919*	0.800*	0.906*
Phytin P vs Total P	0.753*	0.760*	0.696*
Phytin P vs Organic Matter	0.634*	0.560*	0.834*
Phytin P vs pH	NS	NS	NS
Phytin P vs Truog P	NS	NS	NS

* Significant at 1 per cent level.

NS=Not significant at 5 per cent level.